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14. ABSTRACT This final technical report details the status of the Autonomous Vehicle Systems (AVS) Research and Education Laboratory at the University of the Incarnate Word (UIW) located in San Antonio, TX. UIW is a Hispanic-Serving Institution. The AVS Lab was supported by a DoD HBCU/MI equipment grant from February 2014 to January 2015. The equipment purchased from this grant will contribute to the understanding of the control of a formation of multi-agent autonomous systems in uncertain dynamic environments. The educational mission of this laboratory is to introduce new teaching methods into STEM courses at UIW and to provide students opportunities for UAV					
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					19b. TELEPHONE NUMBER 210-829-3160

Report Title

Final Report: Equipment Proposal for the Autonomous Vehicle Systems Laboratory at UIW

ABSTRACT

This final technical report details the status of the Autonomous Vehicle Systems (AVS) Research and Education Laboratory at the University of the Incarnate Word (UIW) located in San Antonio, TX. UIW is a Hispanic-Serving Institution. The AVS Lab was supported by a DoD HBCU/MI equipment grant from February 2014 to January 2015. The equipment purchased from this grant will contribute to the understanding of the control of a formation of multi-agent autonomous systems in uncertain dynamic environments. The educational mission of this laboratory is to introduce new teaching methods into STEM courses at UIW and to provide students opportunities for UAV research. The AVS Lab has been fully operational as of late September 2014. All equipment has been purchased and has been integrated or calibrated into the camera tracking system used for localization within the lab. The AVS Lab had a Demonstration Day on July 31, 2014 for the other regional universities in San Antonio.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

04/28/2015 2.00 Sreerenjini C. Nair, Michael T. Frye, Erik M. Coronado, Yong Qin. Swarm Intelligence for the Control of a Group of Robots, 10th Annual IEEE System of Systems Engineering Conference. 17-MAY-15, . : ,

08/26/2014 1.00 Michael T. Frye, Robert S. Provence. Direct Inverse Control using an Artificial Neural Network for the Autonomous Hover of a Helicopter, IEEE SMC 2014. 05-OCT-14, . : ,

TOTAL: 2

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

None

Patents Awarded

None

Awards

None

Graduate Students

<u>NAME</u>	<u>PERCENT_SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT_SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	National Academy Member
Michael T. Frye	0.00	
FTE Equivalent:	0.00	
Total Number:	1	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

<u>NAME</u>
Total Number:

Names of personnel receiving PHDs

<u>NAME</u>
Total Number:

Names of other research staff

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The Autonomous Vehicle Systems (AVS) Research and Education Laboratory at UIW is part of the Department of Engineering in the School of Mathematics, Science, and Engineering. The long-term research goal for the AVS Laboratory is to investigate techniques for autonomous control, collaboration, and decision-making in unstructured, dynamic, and uncertain nonlinear environments for ground and air vehicles. Using the funds from the HBCU/MI equipment grant, the research from the lab will contribute to the understanding of the collaborative formation control of multi-agent autonomous systems in uncertain dynamic environments. This research will have a direct impact on such DoD mission requirements as:

- 1) Autonomous tracking of a moving target by a formation of rotorcraft UAVs,
- 2) Collaborative control between rotorcraft and ground autonomous vehicles, and
- 3) Autonomous Aerial Refueling between multiple UAVs.

The AVS Lab has purchased the following equipment using HBCU/MI funds:

- 1) Quanser Unmanned Vehicle Systems Laboratory consisting of four programmable ground vehicles and four programmable air vehicles, ground workstations, and optical tracking cameras for vehicle localization,
- 2) Four Draganfly X4-P and four X4-C semi-autonomous helicopters for UAV testing,
- 3) Three Festo Robotino programmable robots for ground formation research and which will interface with the Quanser Unmanned Vehicle Systems Laboratory,
- 4) One Quanser 2 Degree of Freedom Helicopter for real-time UAV control testing,
- 5) 38 Lego Mindstorm EV3 and Hitechnic Sensors for use in feedback control and autonomous systems for STEM undergraduate and High School projects, and
- 6) 5 MATLAB and Simulink licenses for software development.

The AVS Lab has been fully operational as of late September 2014. All equipment has been purchased and has been integrated or calibrated into the camera tracking system used for vehicle localization within the lab. The PI took a two day flight training course for the Draganfly autonomous helicopters in July 2014. The AVS Lab had a Demonstration Day on July 31, 2014 for the other regional universities located in San Antonio, TX.

During Summer 2014, six High Schools students participated in a daylong event on autonomous robots using the Lego Mindstorm EV3. This robotics workshop will be used as a pilot study for next summer when more High School students will be invited. Finally, the PI was a mentor for a High School Senior in the Northside Independent School District Independent Study Mentorship Program for Fall 2014 and Spring 2015 Semesters. The student researched path planning using the EV3 robots.

During the Fall 2014 Semester, the AVS Lab was used for a Machine Learning and Robotics Course with 11 Engineering Students and for a Senior Design Project with two Engineering Students. The Machine Learning Course studied artificial intelligence with applications to autonomous vehicles and robots. The Senior Design Project investigated the wireless control of an autonomous robot. Additionally, a graduate Electrical Engineering student from the University of Texas at San Antonio (UTSA), worked in the lab this previous Fall 2014 as part of an Independent Study course at UTSA. The graduate student was researching nonlinear control methods for autonomous helicopter hover. There are currently four UIW undergraduate engineering students participating in faculty led autonomous vehicle control research in the AVS Lab.

The PI has been leading an effort in the AVS Lab investigating the interaction of ground-based robots and air vehicles to perform a collaborative logistical mission. The objective is the autonomous movement of cargo between remote locations; the cargo is flown autonomously by an air vehicle to a new point, lifted downward to a waiting ground robot, and then deployed by the robot to another location. As a first step to demonstrating this objective, the PI has been investigating a Machine Learning technique using Direct Inverse Control for the autonomous hover of a rotorcraft with externally slung loads. Initial research results in autonomous hover were submitted to an engineering conference this past Fall 2014. Additionally, the PI is investigating handling qualities for autonomous rotorcraft vehicle.

Technology Transfer

None